



State of CERES



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NASA Langley Research Center, Hampton, VA



Earth Radiation Budget Workshop, October 18-21, 2016
ECMWF, Reading, UK

CERES Meeting

Review status of CERES Instruments and Data Products:

- Status of CERES
- CERES Terra, Aqua, S-NPP SW/LW/TOTAL Channel Calibration Update
- CERES FM6 and RBI Update
- MODIS & VIIRS Cloud Algorithm & Validation Status
- ADM, SOFA, SARB and TISA Working Group Reports
- EBAF-TOA & EBAF-SFC Edition 4 Updates
- FLASHFLUX Update
- Data Management Team Update: Terra/Aqua/S-NPP
- Atmospheric Sciences Data Center (ASDC) Update
- CERES Communication Activities

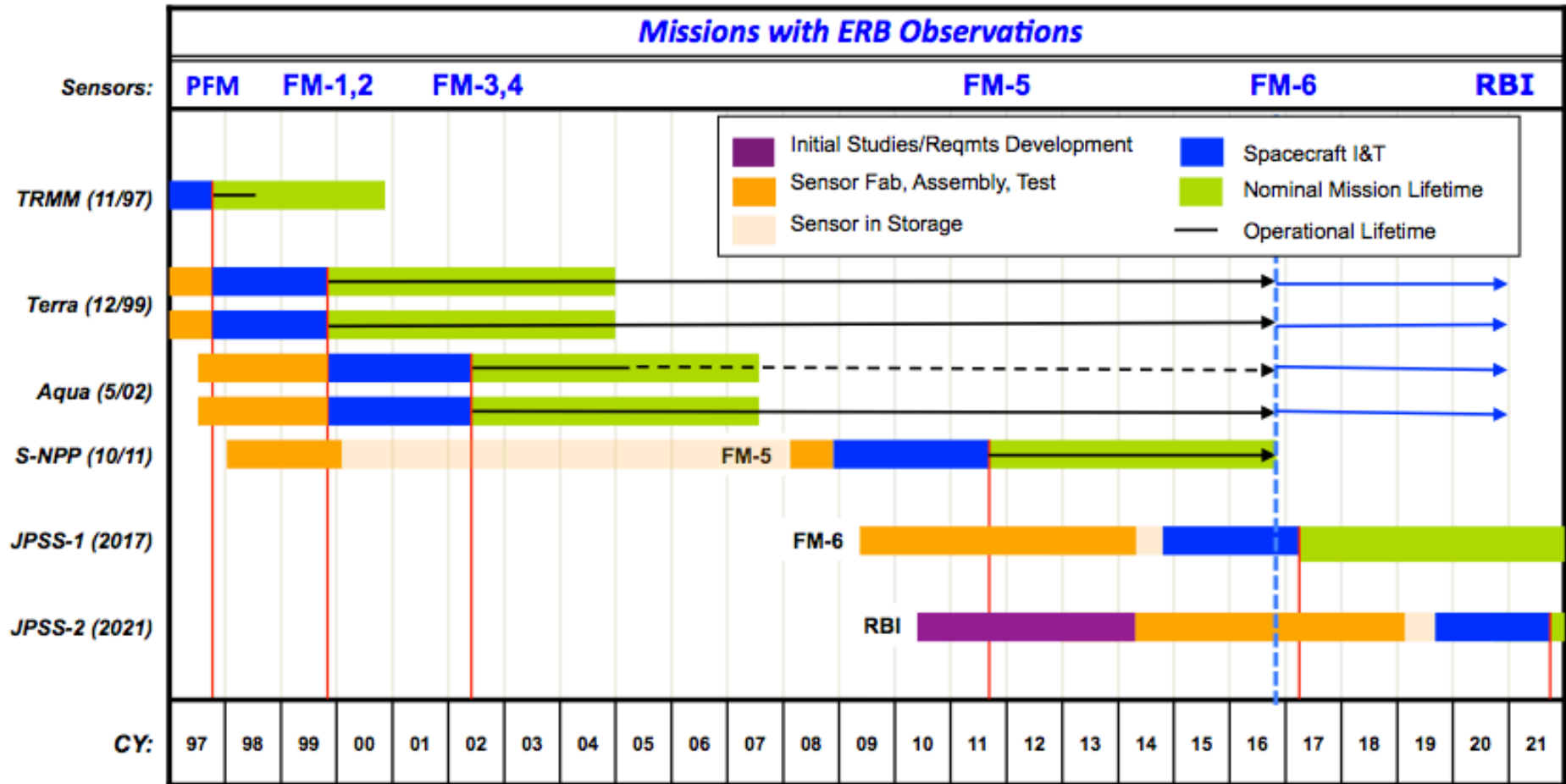
CERES Team Leads

- **Principal Investigator: Norman Loeb**
- **Project Scientist: Kory Priestley**

CERES Working Groups:

- **Instrument: Kory Priestley**
- **Clouds: Pat Minnis (Lead); Bill Smith Jr., (Deputy)**
- **Inversion: Wenying Su**
- **SOFA: David Kratz**
- **SARB: Seiji Kato**
- **TISA: David Doelling**
- **ERBElike: Takmeng Wong**
- **FLASHFlux: Paul Stackhouse & David Kratz**
- **Data Management: Jonathan Gleason**
- **ASDC: John Kusterer**

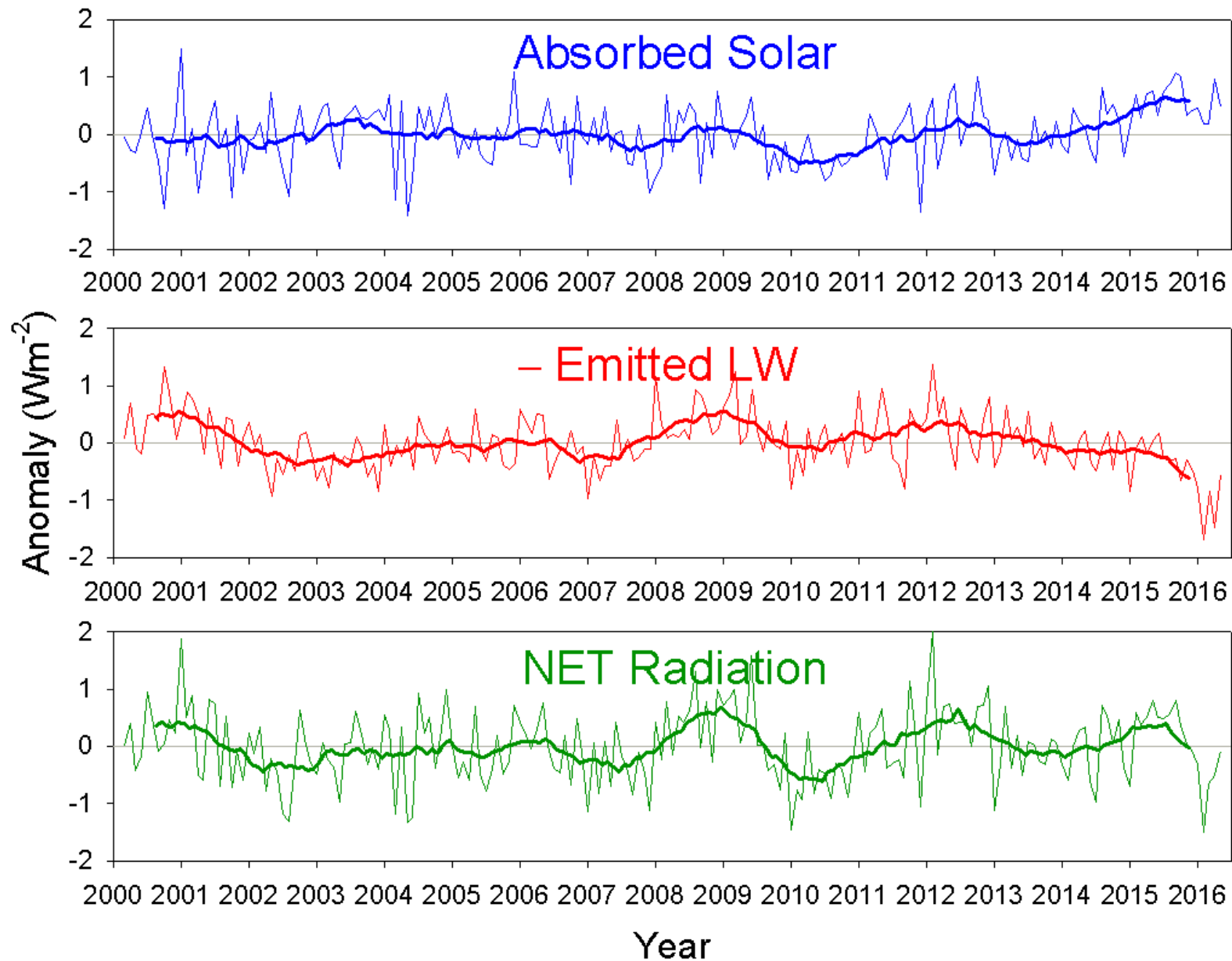
CERES & RBI Flight Schedules



- Currently, 5 CERES instruments fly on 3 satellites: Terra (L1999), Aqua (L2002) and SNPP(L2011).
- CERES FM6 will fly on JPSS-1 in FY17 (2nd Qtr). The CERES follow-on instrument (Radiation Budget Instrument, or RBI) will fly on JPSS-2 in FY21 (4th Qtr).

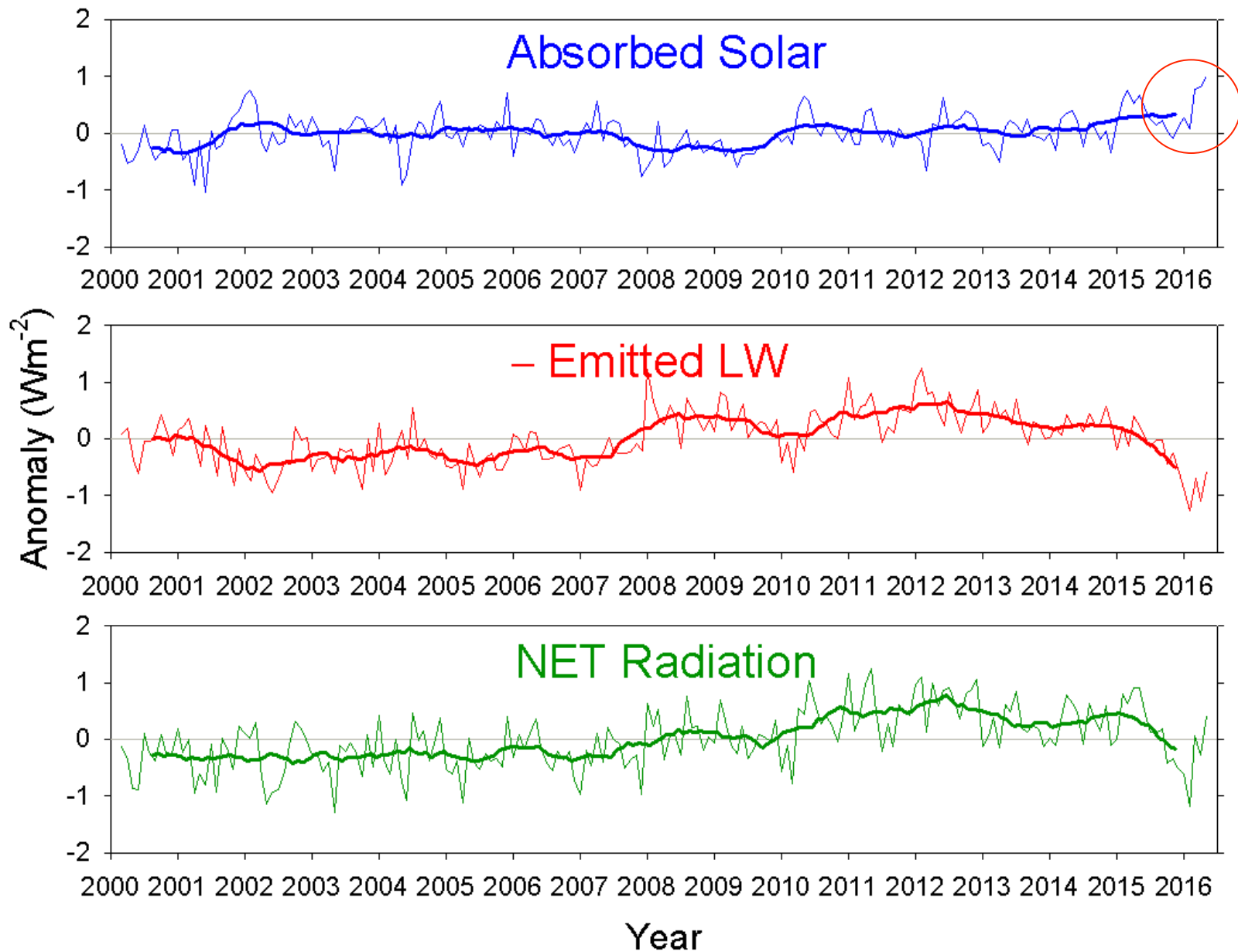
Global TOA **All-Sky** Radiation Anomalies

(CERES_EBAF_Ed2.8; 03/2000 – 5/2016)

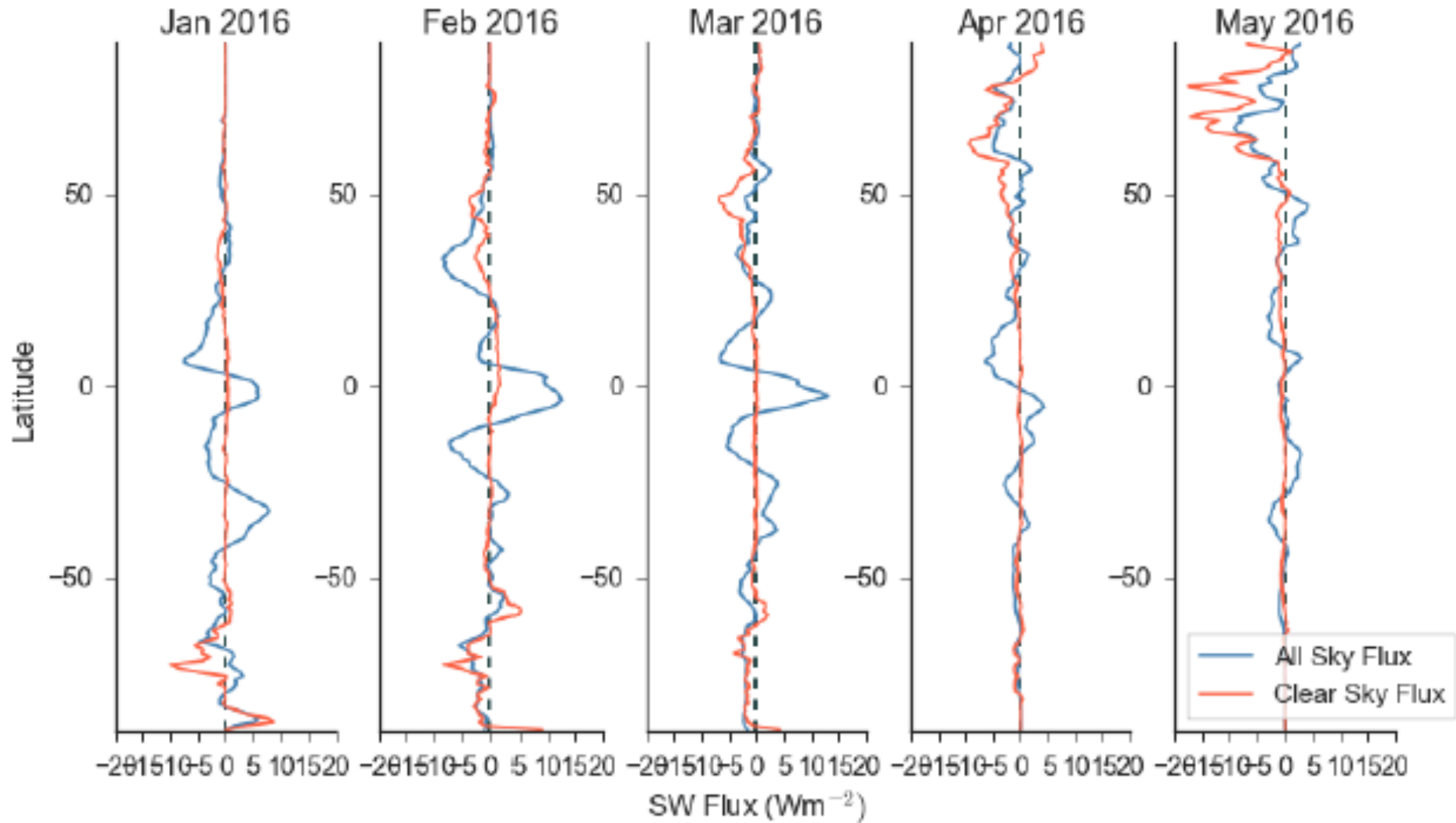


Global TOA **Clear-Sky** Radiation Anomalies

(CERES_EBAF_Ed2.8; 03/2000 – 5/2016)



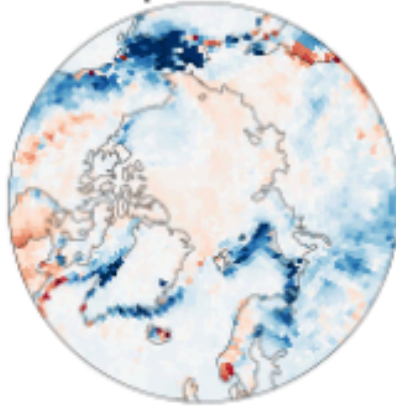
Anomalies in Zonal Mean Reflected SW TOA Flux



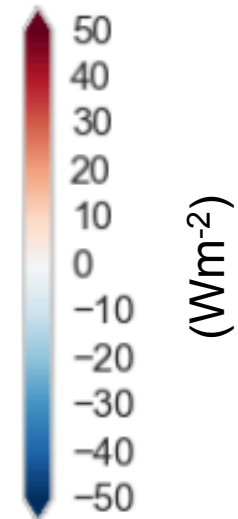
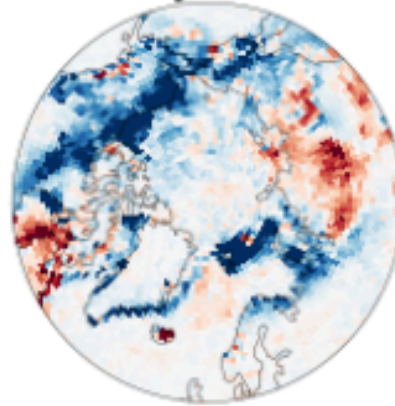
- April & May 2016 clear-sky anomalies are most pronounced poleward of 60°N.

SW Clear-Sky TOA Flux Anomaly

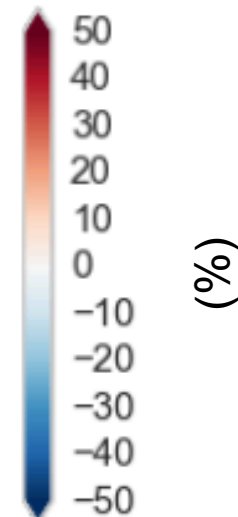
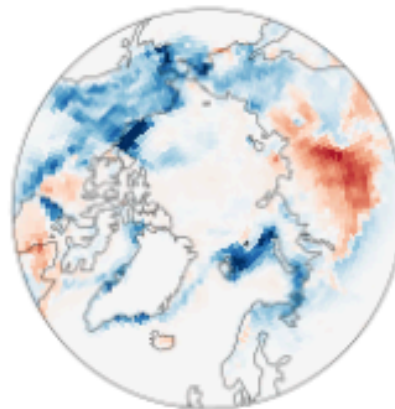
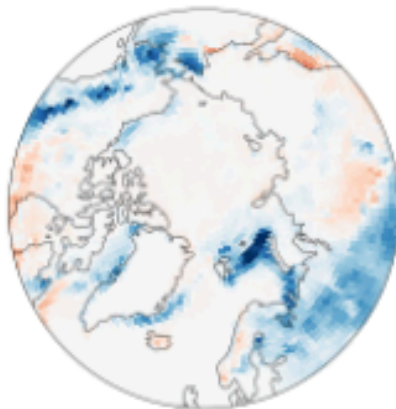
Apr 2016



May 2016



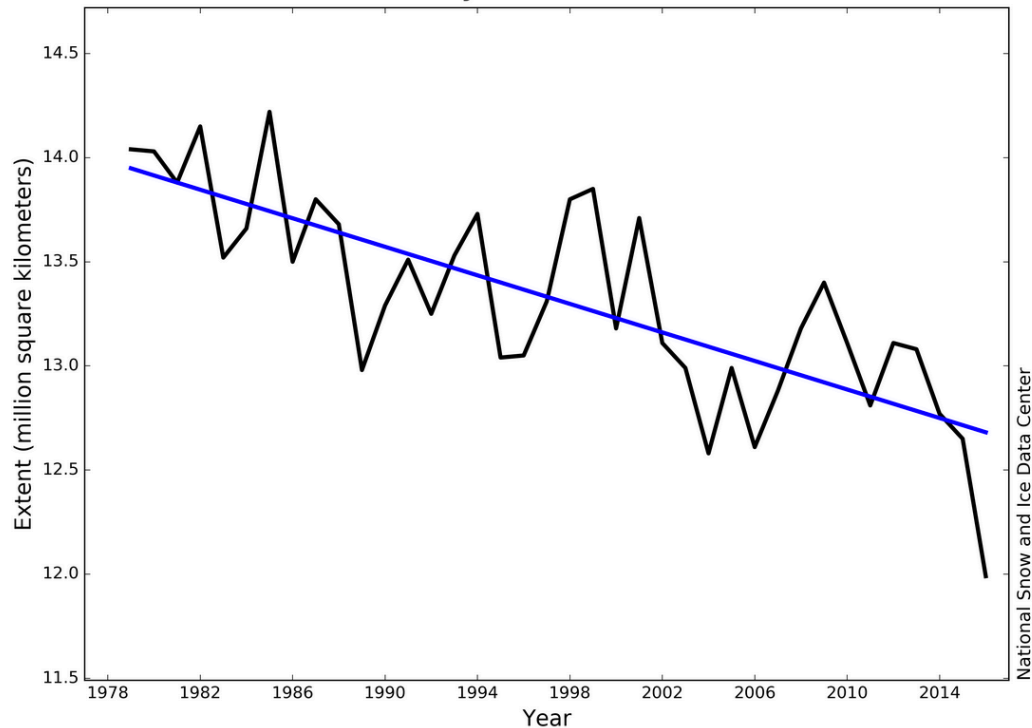
Snow/Ice Anomaly



- Decreases in both sea-ice and snow over land contribute to negative SW TOA flux anomalies.
- Areas of very low snow cover anomalies in North America, Western-Russia and Eastern Siberia have a significant effect on the flux anomalies.

Arctic Snow/Sea-Ice - 2016

Average Monthly Arctic Sea Ice Extent
May 1979 - 2016



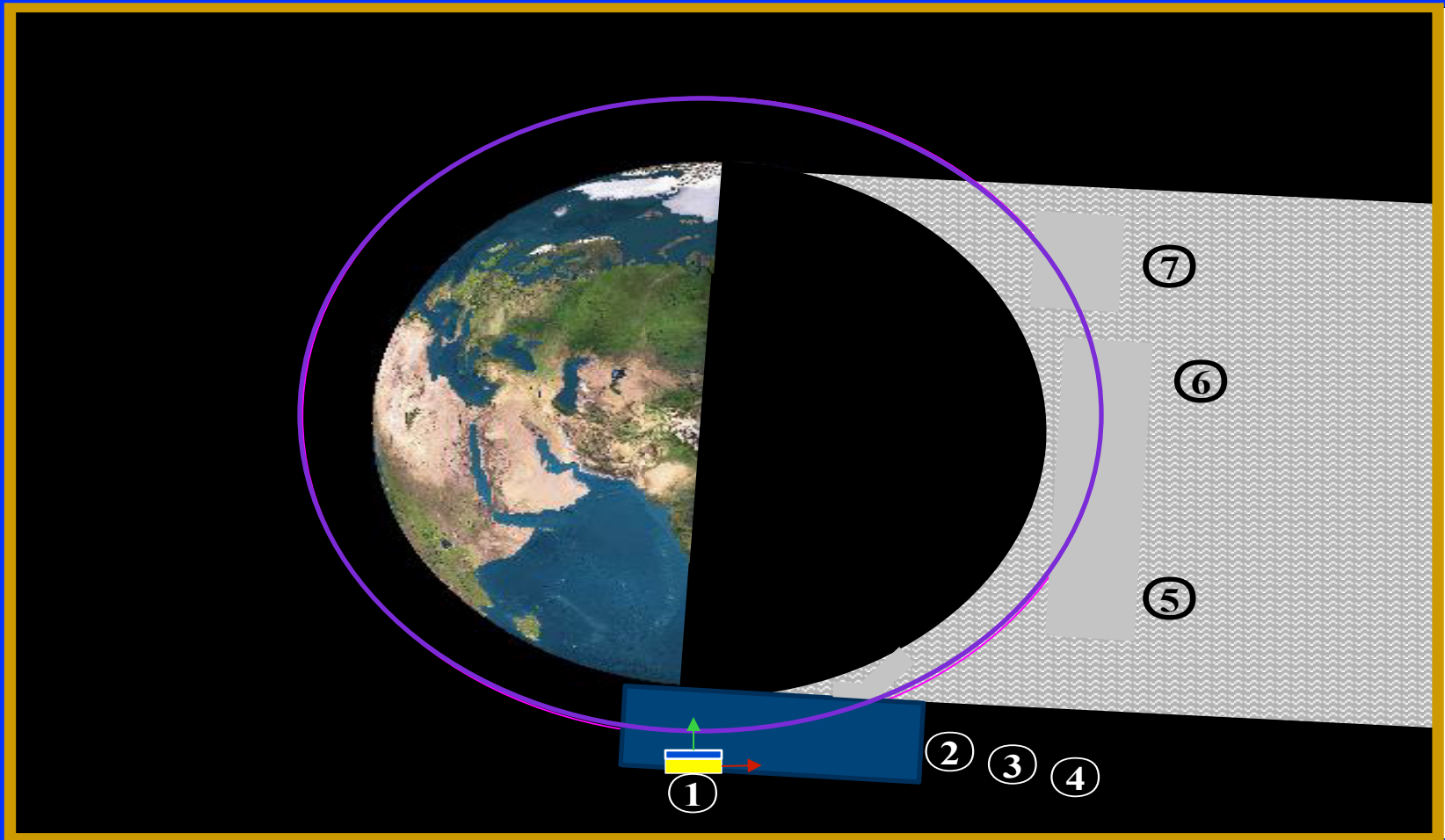
- Jan, Feb, Apr & May 2016 set new record lows for those months for the period of satellite observations.
- Snow cover in the Northern Hemisphere was the lowest in fifty years for April and the fourth lowest for May.

- An unusually early retreat of sea ice in the Beaufort Sea and pulses of warm air entering the Arctic from eastern Siberia and northernmost Europe in part drove below-average ice conditions.
- However, September 2016 was only the fifth lowest in the satellite record, as summer 2016 saw unusually low pressure over the central Arctic Ocean.

Terra Lunar Deep Space Calibration (LDSC) Maneuver

- A DSC maneuver is an accelerated 240 degree pitch-over (360 relative to local horizon) during S/C night that provides observations of the cold background of deep space and an option for a lunar viewing.
- Two previous DSC maneuvers were executed in 2003:
 - March 26 maneuver was a deep space calibration (DSC)
 - April 14 maneuver was both deep space and a lunar calibration (LDSC).
- A LDSC provides the Terra instrument teams observations that can be compared against the LDSC in 2003.
 - Can be used to verify calibration changes from onboard calibration sources over the lifetime of the mission.
 - **A LDSC maneuver is scheduled for August 2017.**

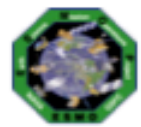
DSC Concept Diagram (Animation)



- Blue block on S/C is instrument deck

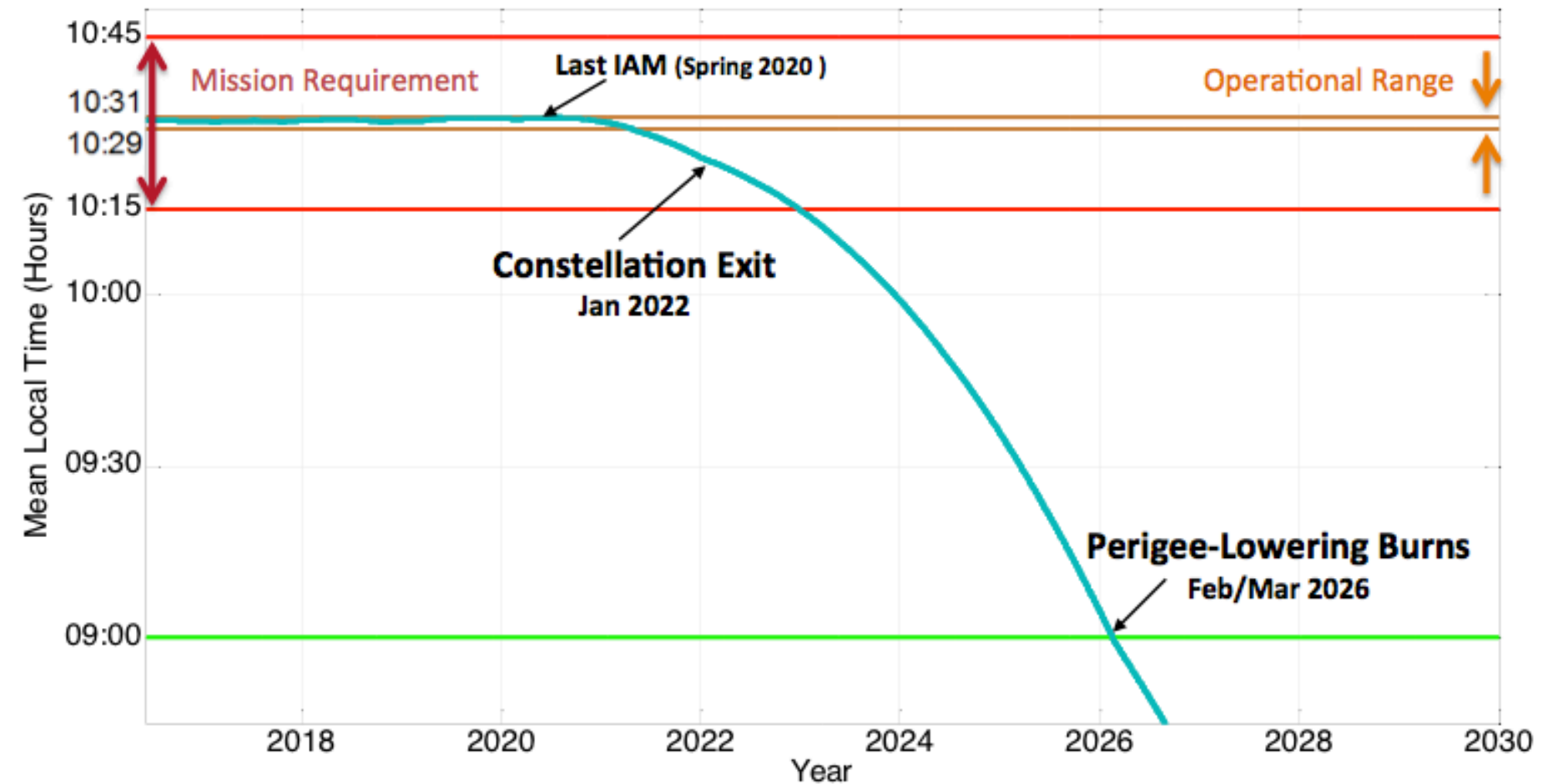
Terra Extended Mission Options

- In 2015, the A-Train Mission Operations Working Group (MOWG) unanimously approved a new exit plan that reduced the constellation exit from a 19-km lowering to 4-km.
- The change provides Terra with additional fuel that could potentially be used to maintain the current MLT and altitude until fall 2021 (3 years longer than original plan).
- However, this would increase the time before orbital reentry to 50 years after end of mission (when 9 am MLT is crossed).
 - The current requirement is 25 years after EOM.
- Originally Terra was exempted from the orbital debris requirements, but now a waiver for any requirements not met because of operational extension decisions is needed.
- Various exit plans have been proposed by the Terra Project.

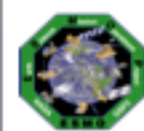


Proposed Plan (Option 1)

Mean Local Time



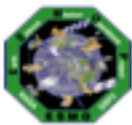
- Maintain the current MLT and altitude until fall 2021 (3 years longer than original plan) before exiting constellation.
=> 20+ year Terra record at constant altitude and MLT.



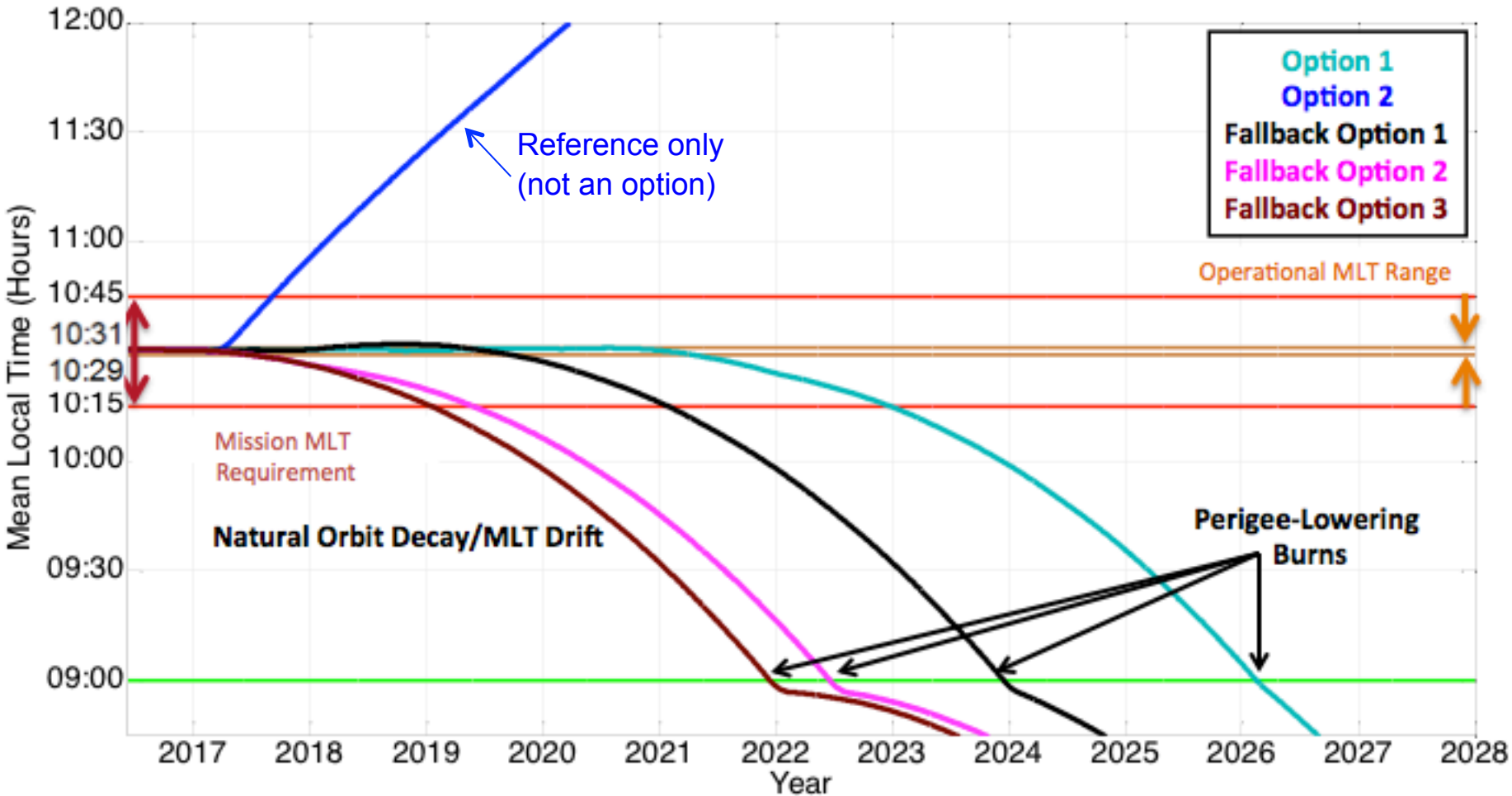
Fallback Option Overview

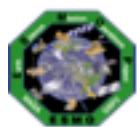


- **All Fallback Options were developed in case the Proposed Plan (Option 1) is not approved by NASA HQ**
 - Attempts to balance science vs. debris/time on orbit goals
- **Fallback 1 - Maintains both MLT & altitude until after the Lunar Deep Space Calibration (LDSC) scheduled for August 2017**
 - LDSC is attempting to replicate the 2003 maneuver to greatest extent possible
 - Results will be compared to validate ASTER science mission data
- **Fallback 2 - Maintains altitude until after the Lunar Deep Space Calibration scheduled for August 2017**
 - Holds altitude for LDSC in August 2017
- **Fallback 3 - Maintains altitude for as long as possible before we get close to another mission**
 - Holds altitude for LDSC in August 2017 and beyond
 - Allots MISR until 2021 to get their science processing updated to account for lower altitude

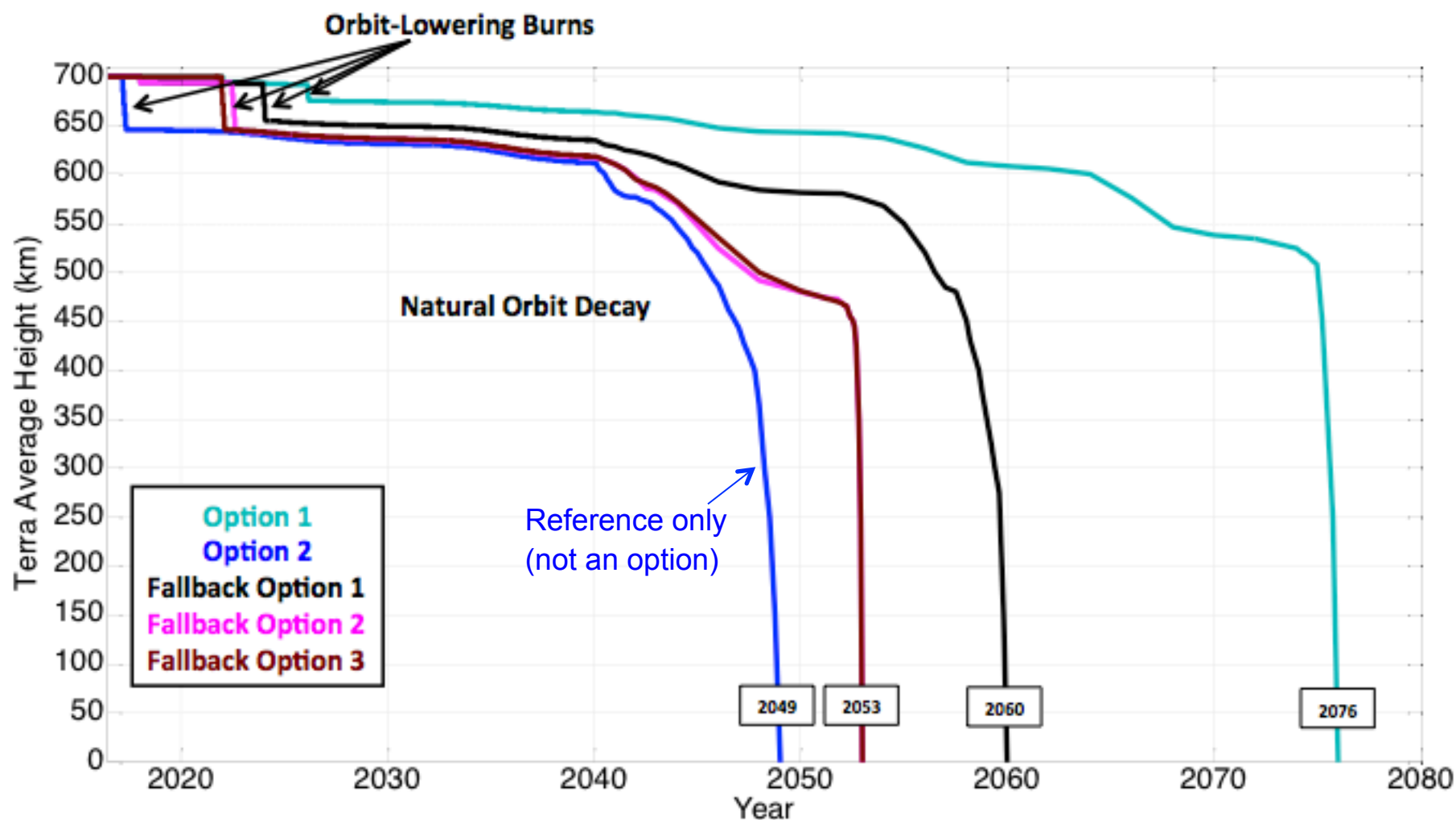


Lifetime Mean Local Time





Lifetime Orbit Altitude





Option Summary

Time-on-Orbit Comparisons



Decommissioning Plan	Science MLT Violation (10:29 AM)	Mission MLT Violation (10:15 AM)	Exit Year/ Lower Alt	De-orbit Year	# of de-orbit burns	Final Apogee (km)	Final Perigee (km)	End of Mission (EOM)	EOM to Reentry (yrs)	Reentry date	Large Object Collision
Option 1	2021	2022	2022	2026	6	702.31	654.21	2026	50	2076	1.10%
Option 2	N/A	N/A	2017	2017	18	705.08	592.37	2017	32	2049	0.49%
Fallback Option 1	2019	2021	2018	2024	14	701.45	613.61	2024	36	2060	0.63%
Fallback Option 2	2017	2019	2018	2022	18	701.00	591.77	2022	31	2053	0.45%
Fallback Option 3	2017	2019	2021	2022	18	700.26	596.78	2022	31	2053	0.46%

- Planned options provides maximum mission life but longest reentry time**
- Fallback options attempt to compromise science with debris risk**
 - Fallback Options 2 & 3 actually beat Option 2 (Decommission ASAP) by taking advantage of solar flux & still provide additional science benefit

- Reference Only
- Planned Option
- Fallback Options
- Key Columns

Note: 1) An A/M Ratio of 0.0099 was used in the DAS 2.02 Time-on-Orbit tool. This was calculated using Terra's tumbling area.
 2) Reentry times calculated using maximum apogee and perigee values instead of average values (conservative)

Terra Waiver Request: Current Status

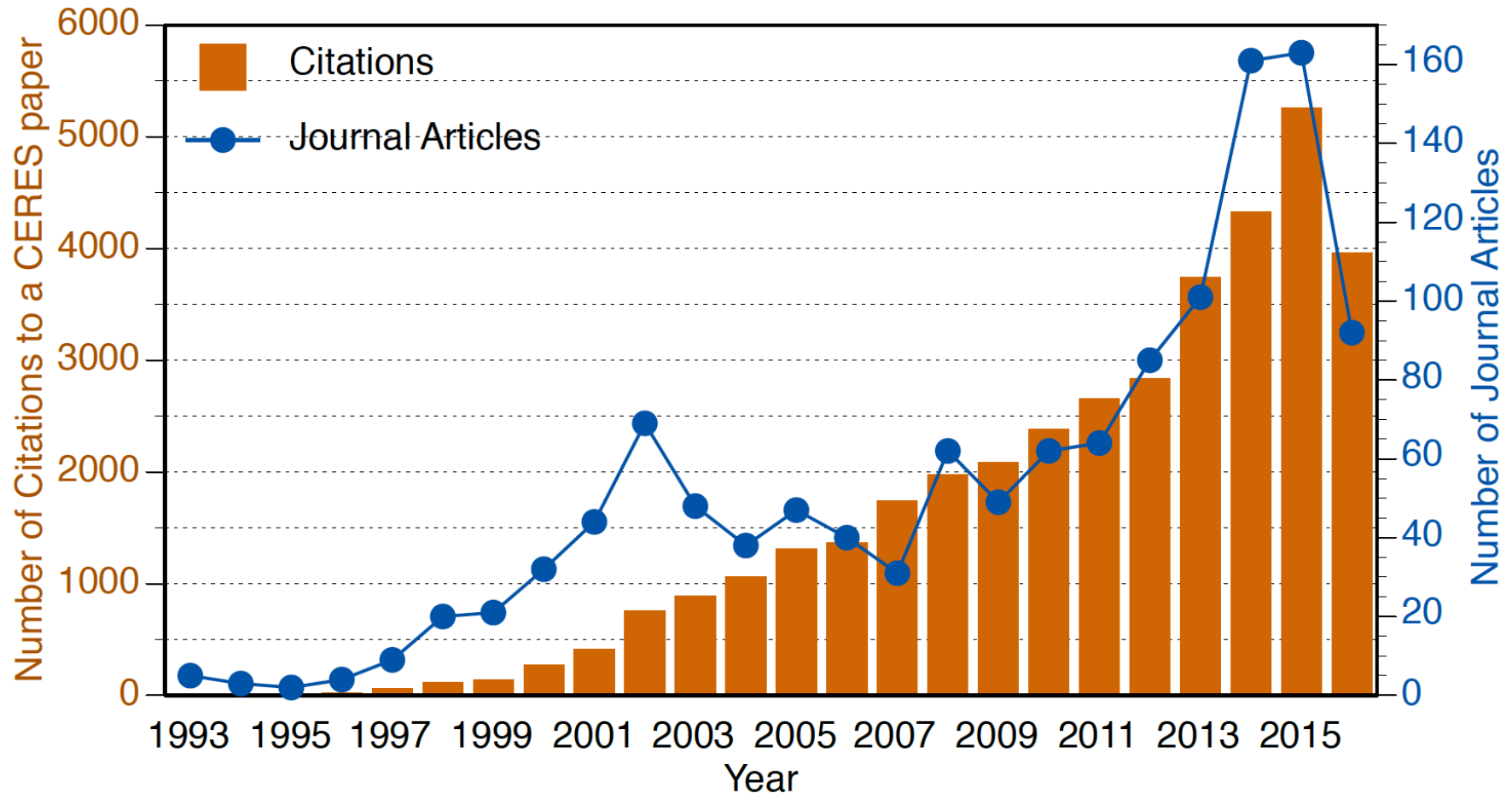
- Both Terra Science and Constellation MOWG have concurred with recommended options.
- Terra-appointed review panel strongly endorsed Option 1.
- The various options are under review at NASA HQ Earth Science Directorate (ESD).
- NASA ESD wants an independent review panel to assess science impacts of various options.

CERES Reviews During Coming Year

- 1) Earth Radiation Budget Science PPBE Review (May 5, 2017)
- 2) Earth Radiation Budget Science Team Review (May, 2017)
- 3) Terra, Aqua and S-NPP Senior Reviews
 - Proposals to be submitted in early March 2017

CERES Journal Publications and Citation Counts

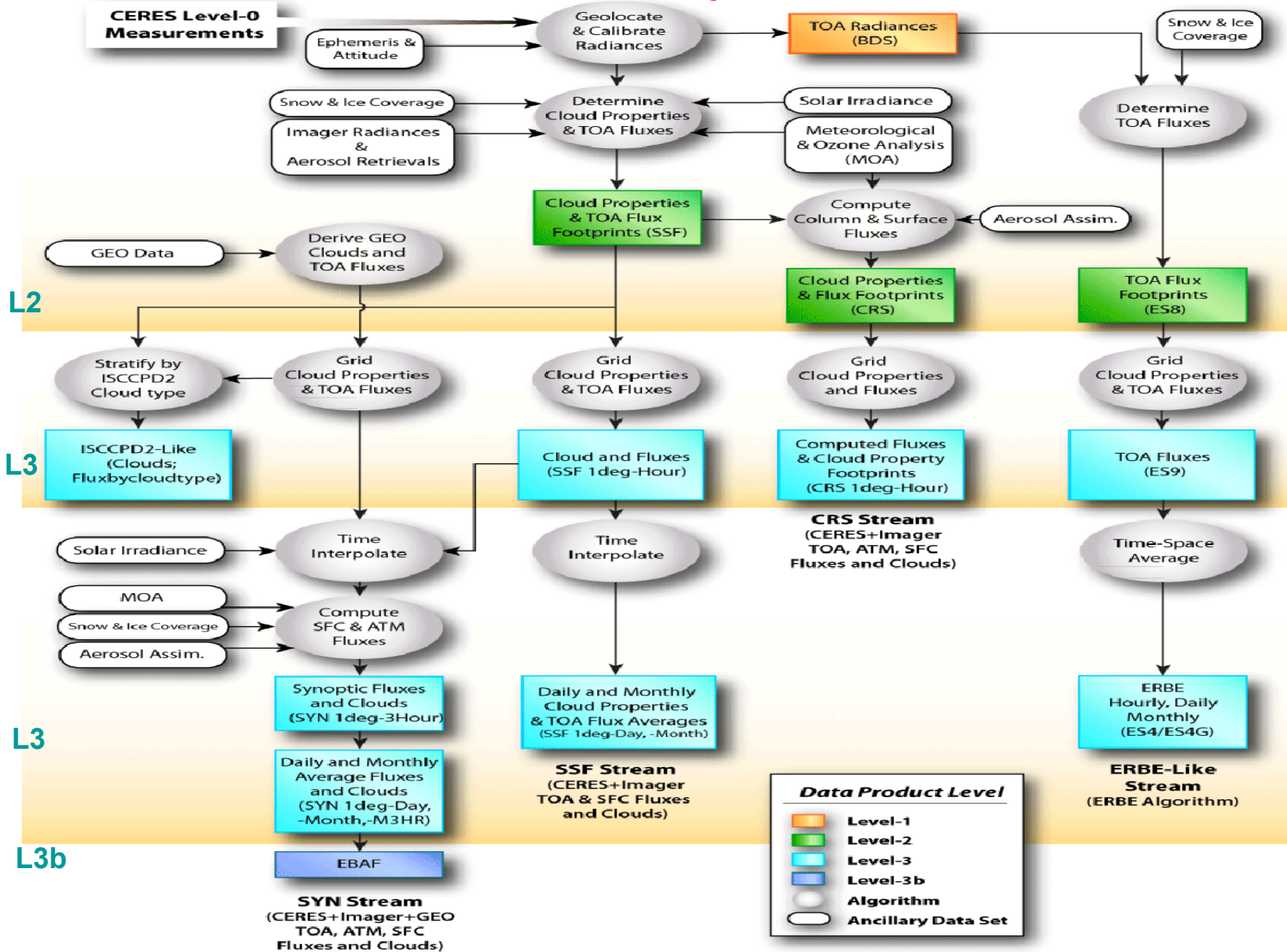
(For Papers Between 1993-2016; Updated October 12, 2016)



- Total number of peer-reviewed journal articles: 1,252
- Total number of citations to CERES papers: 37,410

(Compiled by Anne Wilber & Dave Kratz)

CERES Data Processing Flow



Number of Unique Users by CERES Data Product (through September 30, 2016)

Level	Product	2010	2011	2012	2013	2014	2015	2016
1b	BDS	11	9	14	19	14	11	10
2	SSF	84	77	138	223	247	253	211
	FLASH_SSF	25	8	15	23	30	61	30
	C3M	31	32	33	37	28	55	44
	ES8	22	20	18	31	16	21	15
	SSF-MISR	9	4	2	5	4	2	1
3 & 3b	EBAF-TOA	72	160	346	484	579	580	414
	EBAF-Surface			147	289	375	424	359
	SYN1deg	70	139	188	331	375	431	389
	SSF1deg	77	126	107	157	166	160	151
	ISCCP-D2like	17	12	37	57	41	40	38
	ES4	59	36	11	27	19	13	11
	ES9	21	12	5	13	9	5	5
	FLASH_TISA	17	18	20	17	15	15	25

CERES Terra and Aqua Edition 4 – Status

- Instrument gains and SRFs: Delivered
 - Improvement to Aqua SW part of TOT SRF.
- CERES Clouds code: Delivered.
 - Increased cloud fraction (more consistent with CALIPSO).
 - Decreased cloud optical depth (more thin clouds).
 - Significant improvements to polar cloud mask.
- Inversion (ADMs and SOFA) code: Delivered.
 - 2nd generation CERES ADMs; Improved parameterized surface fluxes.
- SARB and TISA code: **Partially delivered.**
 - Use of 5-channel 1-hourly GEO cloud retrievals.
 - Consistent reanalysis and MODIS calibration throughout.
 - SYN1deg to be released 1-hourly, 3-hourly, daily and monthly.
 - Consistent non-GEO and GEO TISA products (all GMT).
 - Improved to Fu-Liou RT code and ancillary inputs (e.g., Ed4 clouds +overlap, surface albedo, MATCH aerosols).
 - EBAF-TOA (**anticipated release January 2017**)
 - EBAF-SFC (**anticipated release April 2017**)

CERES Terra and Aqua Data Product Availability

Data Product	Level	Ed2.8	Ed3.0	Ed4.0
BDS	1	-	05/2016	05/2016
SSF	2	-	05/2016	05/2016
SSF1deg	3	-	04/2016	11/2015
SYN1deg	3	-	04/2016	Anticipated 03/2017
ISCCP-D2like (CldTypHist)	3	-	05/2016	Anticipated 03/2017
EBAF-TOA	3b	05/2016	-	Anticipated 01/2017
EBAF-SFC	3b	02/2016	-	Anticipated 04/2017

Edition1 Product Availability

Product	Platform	Processed through	Current	Publically Available
BDS	S-NPP	August 31, 2016	Yes	Yes
SSF	S-NPP	August 31, 2016	Yes	Yes
SSF1deg-Hour	S-NPP	August 31, 2016	Yes	Yes
SSF1deg-Day/Month	S-NPP	August 31, 2016	December 2016	No
SYN1deg	Merged		March 2017	No

- SSF1deg-Day/Month products will be reprocessed.
- SYN1deg will start late fall.

COVE

- DOE turned Ches Light over to GSA for excess; GSA put Ches Light up for auction last spring.
- New owner has been identified. Private individual. Not certain how platform will be used.
- New owners willing to rent to us so we can continue to operate BSRN & AEORNET.
- BSRN instrument suite is operating autonomously at COVE. AERONET instrument is broken.
- A 2nd BSRN instrument suite is operating at CAPABLE.
- Approval to operate MPLNET at CAPABLE was finally granted.



Upcoming Conferences & Meetings of Interest

American Geophysical Union

- December 12-16, 2016, San Francisco, CA

AMS Annual Meeting

- Jan 22–26, 2017, Seattle, WA

3rd International A-Train Symposium 2017

- April 19-21, 2017, Pasadena, CA

EGU General Assembly

- April 23-28, Vienna, Austria.

Spring 2017 CERES Science Team Meeting

- May 9-11, NASA LaRC, Hampton, VA.

Gordon Research Conference: Radiation & Climate

- July 16-21, Bates College, ME.

Other News

- CLARREO Pathfinder mission will fly on ISS ~2020 (reflected solar spectrometer only).
- RAVAN launch October 2016.

End